

## BEHAVIOR IN TRAFFIC CONFLICT SITUATIONS

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**Abstract**—The aim of the study was to find typical errors of traffic participants leading to frequent traffic-conflicts. For this purpose we registered conflicts and the types of behavior leading to them by observing 201 subjects driving along a standardized route and describing their behavior. The data collected this way, together with information about the driving record of the subjects obtained in exploration talks, were used to describe different groups of drivers by analyzing which forms of behavior affecting traffic safety were typical. In addition, the importance of communication and the genesis of conflicts were investigated.

### 1. INTRODUCTION

In Austria, as in other European countries, scientists are trying to gather information on traffic conflicts. In addition to accidents, traffic conflicts should be used as a criterion for the dangerousness of certain sections of the road network and as a criterion for the adaptation of traffic participants to traffic conditions. Together with the analysis of accidents, the analysis of traffic conflicts should provide data which help in planning measures for enhancing traffic safety.

#### 1.1. *Questions central to the problem*

Two questions are germane to the present study:

- (i) Can certain types of the traffic participants' behavior be identified which are related to traffic conflicts?
- (ii) Did persons showing behaviors which result in frequent traffic conflicts also actually get involved in accidents more often than others?

#### 1.2. *The aims of the study*

One aim was to operationalize those parts of driving behavior which are assumed to be causes of traffic conflicts and/or accidents and to register such types of behavior on as large a sample of persons as possible. It was also necessary to find out the frequency with which these same persons get involved in traffic conflicts along a standardized route.

We further endeavored to collect data about the traffic accidents these persons had hitherto had.

The next step was to analyze the interrelationship between driving behavior (especially errors in driving behavior on a standardized route), the frequency of traffic conflicts on a standardized route and the number and kinds of traffic accidents each person had had so far.

### 2. THE CRITERIA "TRAFFIC CONFLICT" AND "ACCIDENT"

The criterion most frequently used in traffic safety analysis is and has traditionally been the traffic accident. But when grading persons on their adaptation to road traffic, there is one problem inherent to the logic of accidents: A person's accident history does not necessarily reflect the quality of his driving habits. Statistically speaking, accidents are rare events; even a bad driver can manage to stay accident-free for a relatively long period. Moreover, accident statistics neglect many aspects which are especially germane to traffic safety *per se*.

- (i) How often do other traffic participants compensate for one's errors, errors which otherwise would lead to an accident?

(ii) In how many accidents did a person get involved without being guilty according to the letter of the law but *de facto* guilty due to improper or unperspicacious etc. driving behavior? The question of judicial versus moral guilt crops up.

Moreover, accidents are not useful at all for behavioral analysis. One cannot expect to witness an accident during a short driving test, much less to be able to describe the event and to investigate the causes of it. Besides, if accidents were to be expected during a driving test, it would certainly be difficult to find observers!

Klebensberg *et al.* [1970], Schwerdtfeger and Zimolong [1973], Klebensberg [1982], Risser *et al.* [1982], Gstalter [1983] and others discuss the disadvantages of accidents as criteria for traffic safety in detail.

For the above mentioned reasons we tried to find other criteria, and it was quite obvious to us that traffic conflicts should be used to judge persons' driving performance as well as the dangerousness of specific segments of the road network:

A traffic conflict is an observable event which would end in an accident unless one of the involved parties slows down, changes his direction, or accelerates to avoid a collision. The later one of the parties involved reacts correspondingly, the higher the danger of a collision.

For more information about the traffic conflict as a criterion for traffic safety, see Hydén [1977]; Erke, Gstalter and Zimolong [1978]; Hydén and Ståhl [1979]; Spicer *et al.* [1980]; Zimolong [1982]; Risser *et al.* [1982] and Gstalter [1983].

### 3. BEHAVIOR RELATED TO TRAFFIC SAFETY

There is no doubt that most road accidents are caused by the erroneous behavior of road users, although persons who have gotten involved in traffic accidents normally deny their own fault. Nevertheless, in accident statistics, one can find a few special types of behavior which are connected to traffic accidents.

To us it seems quite obvious to expect that the same types of errors are also causes of traffic conflicts.

Some examples are the following. (i) Excessive speed or poorly adapted speed. (ii) Too small a distance to the preceding car. (iii) Violations of the right-of-way. (iv) Many other poorly adapted types of behavior.

Traffic regulations quite explicitly name those violations which increase the probability of accidents in the opinion of lawmakers. If one considers traffic safety to be a variable varying between correct behavior (meaning behavior according to a defined standard) and traffic conflicts and/or—in a further step—accidents, then errors in the behavior of road users should be found somewhere in between those two extremes. Using a model by Klebensberg [1964] one could imagine these relationships as shown in Fig. 1.

Figure 1 also illustrates that the frequencies of events diminish as behavior approaches the dimension of actual accidents.

When talking about behavior as defined by a standard, one could define errors in driving behavior as negative deviations from that standard. If there are negative deviations, it would only make sense that there were also positive deviations. Such positive deviations of behavior according to a defined standard should also have some relationship to traffic safety.

Last, but not least, in discussing special types of behavior which could influence traffic safety we discovered another aspect which in our opinion is central to the issue. Many studies

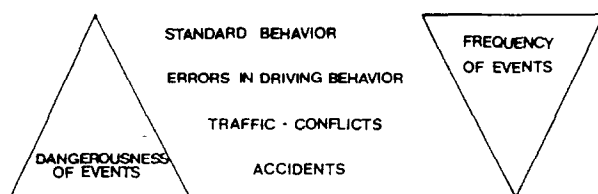


Fig. 1. The steps from behavior as defined by a norm to actual accidents.

in the German-speaking countries during the last years have shown that communication between road users has quite an impact on traffic safety [Kroj and Spoerer, 1974; Bauer *et al.*, 1980a; Bauer *et al.*, 1980b; Savigny, 1980; Merten, 1981; Bauer *et al.*, 1981, see Section 3.3.].

### 3.1. *Errors in driving behavior*

Searching for types of behavior which lead to traffic conflicts or to accidents one would expect an accident to have been preceded by dangerous behavior (e.g. behavior that left no safety margin or behavior that left the outcome to chance, thus increasing the probability of an accident).

As a rule, behavior not consonant with traffic regulations is at the same time dangerous behavior. For example, ignoring a red traffic light within the confines of urban areas where structures impair the field of vision is indeed always dangerous. But there are situations where illegal behavior does not seem to be dangerous: As an example, one has only to think of speeding on an empty and clean two- or three-lane road.

So, when trying to identify types of behavior which lead to accidents one will have to consider both the legality as well as the degree of danger coincident to any certain behavior as two very important aspects. A third aspect certainly is the ability of road users to communicate with other road users in a way that excludes misunderstandings, including the ability to recognize the intentions of others: behavior that leads to misunderstandings or behavior that is caused by a misunderstanding almost certainly represents danger [Bauer *et al.*, 1981]. Those three aspects of traffic safety reducing behavior were analyzed together with their relationships to traffic conflicts and accidents.

One would define standard behavior as behavior recognizable to the expert by not showing the above-mentioned traffic safety reducing aspects.

### 3.2. *Positive deviations of driving behavior from a defined standard*

If it is possible to define negative deviations from a defined standard, it should likewise be possible to define positive deviations. We tried to describe such positive deviations (we call them "ideal behavior" or "ideal solutions of situations"). In some situations there is a better solution than the standard one, the driver taking more precautions than the strictly necessary ones, thus raising security and fluency of traffic. Ideal behavior is characterized by the fact that the behavior of other road users is taken into account. It is to be considered as ideal for the interactive road traffic system, but not necessarily for the individual participant.

Our definition includes another important factor: Ideal behavior excludes conflicts whereas standard behavior does not. It is quite possible to become involved in a conflict or an accident while behaving according to a standard, not, however, when performance is at the level of ideal behavior. Ideal behavior prevents such an outcome by considering conflict-stimulating environmental cues with respect to the behavior of other road users.

### 3.3. *Communication*

In an earlier project undertaken by the Austrian Road Safety Board, aspects of communication in road traffic were analyzed from a judicial, a sociological and a social-psychological point of view [Bauer *et al.*, 1980a]. We also collected the opinions of road users in roundtable discussions about advantages and disadvantages of communication in road traffic and about the needs of road users in this respect [Bauer *et al.*, 1980b].

The deliberations in the course of these former projects led to two conclusions:

(i) It is necessary to recognize the implications for one's own behavior in the behavior of other road users; and it is necessary to make oneself understood to the other road users. Of course, omitting necessary information of other road users is one way not to make oneself understood.

(ii) By giving signals, the fluency of traffic can be improved. Road users actually do give signals. Many of those signals, however, are not official, which means they are not explicitly defined by the laws governing traffic. The main problem with non-official signals is that they are at times misunderstood; most of the non-official signals and even some of the official signals are ambiguous. The consideration of these two points resulted in the hypotheses that conflicts quite often are caused by erroneous or misunderstood communication, or just by plain absence of communication.

But "communication" does not only mean plain information (or omitting of information) and reaction to it. It also means deliberate neglecting of rules, thus offending others' rights and/or feelings which might lead to dangerous situations; and it also means renouncing one's own rights with respect to being cooperative and/or polite. No known standards have been established for communication in road traffic so far. Therefore, as a first step, it is necessary to analyze the utility in respect to traffic safety of all communication-aspects between road users and not only those which are a part of a positive or a negative deviation from the standard.

#### 4. PLANNING OF THE EXPERIMENT

In planning an experiment aiming at the analysis of road user's behavior, one can consider the use of laboratory tests resulting in prognoses of future behavior in road traffic. Analyzing driving records is another possibility. The incompleteness of such data renders this approach unsatisfactory, however. The third possibility is observing the behavior of road users while they participate in road traffic, which in our case means conducting driving tests.

In order to collect the kind of data upon which our interest is concentrated, it was obviously necessary to go out into the field and conduct such driving tests. Deviations from the standard behavior, communication with other road users and traffic conflicts can only be analyzed by observing the behavior of road users in actual traffic situations.

As we did hope not to witness actual accidents in the course of our driving tests, we planned in addition to collect information about former accidents from our subjects during the psychological explorations.

##### 4.1. *The driving test*

One can observe persons participating in road traffic in more than one manner. One possibility is to follow a driver who is immediately in front of the observer's own car. The problem inherent to this method is that one sees the results of erroneous behavior but not its genesis (e.g. head movements, handling difficulties, etc.). Another possibility is to observe the behavior of a driver by accompanying him in his own car.

Both methods could influence the subjects to simulate good behavior, or behavior different from their normal one. But already in 1967 Höfner could show that obtrusive observation after some 10–15 min rather leads to an accentuation of the driver's characteristic behavior. So the thing to do is not to start registration before 10 min of the ride have passed. Regardless of the method chosen, it is necessary to observe all the testees on the very same route in order to be able to compare them.

Theoretically, one could give a complete description of a person's driving behavior during the driving test. Each behavioral unit would need to be notated and graded. The result would be a kind of "verbal movie" of behavior. The problems of this type of procedure are as manifold as well investigated and veritably prohibitive to our purposes.

So we reduced the amount of data to be collected. But still (as Sections 4.1.1 and 4.1.2 will show) their number was quite high. We could collect them only by letting two observers register different sets of variables. Thus, considering former driving tests [Quenault and Fuhrmann, 1969; Klebelsberg, Biehl, Fuhrmann and Seydel, 1970; Kroj and Pfeiffer, 1973] we decided to combine two methods:

(i) Deviations from a behavioral standard should be registered. This is a very comfortable method. For an expert it seems to be easy to use and it does not need many preparations. The question is, if by simply counting deviations from a behavioral standard you can differentiate exactly enough between the subjects (free observation).

(ii) Behavior in a group of precisely defined behavioral settings should be described according to a coding scheme (coding observation).

Those methods were to be applied in combination accompanying the subjects in their cars.

4.1.1. *The free observer.* The free observer was to register deviations from a behavioral standard. All kinds of behavior representing a severe offence of the law and/or causing danger

(e.g. increasing the probability of an accident) and/or causing misunderstandings are defined as negative deviations. All types of behavior showing consideration of the various possible reactions (including also illegal reactions) of other road users with respect to conflict-stimulating cues in the environment we defined as positive deviations. (For example: Bus stops and observed subject slows down, obviously knowing that bus passengers sometimes tend to step on the road passing the bus on its front). Additionally, communication between the testee and other road users and traffic conflicts in which the testee got involved had to be described.

As communications we defined all interactions between road users containing at least one information and one necessity to respond to that information. If another road user's information does not imply a reaction of the observed subject, in our definition it is not to be registered as communication.

Three types of communications were to be distinguished: (i) Friendly communications (e.g. cooperative, polite communications); (ii) neutral communications (plain information within the traffic rules); (iii) unfriendly communications (e.g. neglecting rules respective to others' rights or feelings).

Last, but not least, the free observer had to register traffic conflicts. For doing that he was given no means of quantification (e.g. meters or seconds left till the imminent accident), but he had to decide on a strictly semantic level, of course according to the definition given above.

Two kinds of severity of conflicts were to be distinguished.

(i) Serious conflict: Rapid deceleration or emergency braking, rapid or violent change of direction—with a character varying from a lane change to a swerve. The time for the maneuver is too short to consider other vehicles or pedestrians not directly involved in the traffic conflict.

(ii) Slight conflict: Controlled braking or change of direction is necessary to avoid a collision. There is ample time to keep control of vehicles or pedestrians not directly involved in the conflict.

Concerning conflict registration without means of quantification and the two-step scaling of conflict severity, see Höfner and Schützenhöfer [1978]. Standard behavior not occurring as an act of communication or as part of a conflict was to be ignored by the free observer.

A rough definition of these variables is to be found in Section 2 (traffic conflicts) and Section 3 (errors in driving behavior, positive deviations from standard, communications). For more detailed information, see Risser *et al.* [1982, Chap. 3.1].

4.1.2. *The coding observer.* The coding observer was to describe the behavior of the testees along all sections of our test route using a standardized coding system. By means of coding the testees' behavior, we expected detailed descriptions of the behavior before, during and after the events registered by the free observer.

The coding system is constructed in such a manner that one of the alternatives of the behavior to be described can be defined as wrong behavior. This enables a comparison of the description given by the coding observer with the account reported by the free observer. Further, a detailed description of the behavior should provide for data concerning standard behavior, e.g. data in all those situations in which the free observer had been instructed not to register anything.

The following variables are summarized in the coding system:

- (i) use of the blinker (early, late, not at all);
- (ii) accuracy of lane use (extremely on the right or left side of a lane);
- (iii) timing of lane change in the case of obstacles (very early, in the last moment);
- (iv) performance of evasive actions (abruptly, not at all reacting);
- (v) lateral distance to sidewalk or other vehicles (too small);
- (vi) distance to the preceding car (too small, too large);
- (vii) choice of speed (above the speed limit, below the speed limit);
- (viii) continuity of speed (fluctuating);
- (ix) taking care of pedestrians (e.g. lateral distance, speed adjustments, etc.).

All these kinds of behavior are observable along the entire route, independent of the segment thereof.

The following categories of behavior are dependent upon specific sections along the route:

- (i) driving in curves;

- (ii) choice of lane at an intersection with several alternatives for proceeding afterwards;
- (iii) lane change while entering at junctions (e.g. lane change for vehicles not having the right-of-way);
- (iv) choice of traffic lane (right, middle, left);
- (v) performance of lane change (hesitating, abruptly);
- (vi) slowing down before crossroads and/or before turning points (very late or too late; not at all despite necessity);
- (vii) endangering road users who have the right-of-way;
- (viii) behavior in situations, where road users coming from the right have the right-of-way (even in the case that no road user is coming);
- (ix) behavior when right-of-way for the cross traffic is explicitly defined by a traffic sign (also to be observed when no road users are on the road with the right-of-way);
- (x) behavior at stop signs;
- (xi) turning left against oncoming traffic;
- (xii) behavior in front of traffic lights;
- (xiii) driving past other vehicles in the same direction although their speed is above the limit (on highways or more-lane roads);
- (xiv) overtaking other vehicles despite oncoming traffic, despite overtaking being prohibited, etc.

For an exacting description and discussion of these variables, see Risser *et al.* [1982, chap. 3.2].

The results of the free observer and the coding observer were not expected to correspond with each other *a priori*. Instead, we chose to let the two methods of observation function as control mechanisms. We wanted the negative behavior alternatives out of the set of codes and the negative deviations from the behavioral standard registered by the free observer to correspond to each other *a posteriori* as highly as possible.

#### 4.2. Psychological exploration

The necessary information pertaining to the accident record of the last five years and the driving experience (kilometers driven up to now) of our testees was to be obtained via psychological exploration. This was to be a blind exploration, conducted by a psychologist innocent of the results of the driving tests; if exploration occurred before the driving test, we took precautions to delegate a psychologist other than the one who had done the exploration to function as behavioral observer.

Not before the middle of 1984, however, would we be able to validate the subjects' self-responses concerning the accident data against data of their insurance companies ( $r = 0.62$  between the number of self-reported accidents caused or partly caused by the testee and insurance data [Risser, 1984]).

### 5. HYPOTHESES

(i) Conflicts are the result of definable errors in driving behavior; ideal behavior prevents conflicts. Road users showing many errors in driving behavior in the sense of our definition get involved in more conflicts than others.

(ii) Conflicts are the result of poor communication. Conflicts most probably are frequently the result of erroneous, misunderstood, or the absence of necessary communication between road users.

(iii) Conflicts are prestages of accidents. Conflicts and accidents are elements along the same dimensions. We expect persons reporting more accidents in the exploration also to get involved in more conflicts during the driving-test.

### 6. THE EXPERIMENT—THE DATA COLLECTED

The driving tests were carried out on a standardized route in Vienna. Prior to the actual test, the observers were trained on a video-screen and then did pretest observations on about 40 subjects. These practice observations were done by groups of three, to provide for high agreement among the observers facilitated by the possibility for extensive discussions.

### 6.1. *The sample*

It was our aim to administer as many driving tests as possible between March and October (1982)—acceptable months as far as the weather is concerned. To arrive at a reasonable number of subjects we asked for the help of the insurance companies; approximately 2000 clients got a letter from their insurance company asking them to take part in our experiment. Some of them belonged to the group penalized with the highest insurance rate because of the many accidents in which at least part of the blame could be attributed to them, the others belonged to the group paying the lowest insurance rate as a reward for accident-free driving. Approximately 250 persons answered those letters; 112 did, in fact, take part in our experiment, 74 belonging to the lowest insurance rate group and 38 belonging to the highest insurance rate group. The other subjects were recruited from the ranks of the members of senior citizens' clubs, taxi drivers, policemen and students. The study at final count was evaluated on the basis of the data derived from 201 driving tests.

As one can see the sample is not a representative one for Austrian drivers. But it has the advantage of including groups of drivers with extremely different driving records. Comparing them, one should expect clear differences in the data derived from their driving tests.

### 6.2. *Time schedule*

These driving tests were carried out between 15 March 1982 and 28 October 1982 on a standardized route in Vienna. The explorations with the testees took place between the months of June and October 1982.

### 6.3. *The route*

The route was planned to be representative of Eastern Austria, as far as possible. Nevertheless, we did not succeed in integrating a piece of a mountain road into our test route.

Roughly, the route included 40% narrow one- or two-lane city roads, 20% three- or four-lane city avenues, 20% city highways, 10% village roads outside Vienna and 10% rural roads outside Vienna (see Fig. 2).

Weather and road conditions were judged quite evenly as convenient or at least acceptable by the observers. Less than 5% of the rides were carried through with poor weather (e.g. fog or rain) or bad road conditions (e.g. wet).

### 6.4. *The data collected*

Because one coding observer fell ill, we could not get the coding results of 12 subjects; 44 persons could not come to the psychological exploration so the final data are limited to the results of 156 explorations. At the end of the experiment we had information from the following at our disposal: 201 observation sheets under free condition, 189 observation sheets under coding condition and 156 exploration results.

## 7. RESULTS

### 7.1. *Inter-rater correlations and reliability of data collection*

Registering *errors* in sets of driving behavior seems to function in a reasonably objective and reliable way. Comparison of the six free observers by twos (calculated in  $\chi^2$ -approximation of the Mann and Whitney *U*-test) showed acceptable correspondence in 67% of the possible comparisons of pairs of observers. The reliability of the registering of errors in driving behavior is represented by an alpha value (Cronbach  $\alpha = 0.82$ ).

All the results concerning ideal behavior are by far less satisfying. Our impression that ideal behavior can perhaps at best be described as paradigm but not secured as a definition was confirmed in our analyses of objectivity and reliability. Comparing the six of our free observers by twos we found agreeable correspondence only in 52% of the possible comparisons. The reliability index of  $\alpha = 0.35$  is even more disappointing.

As for the registration of communication processes by the free observers, the results are not that bad but still not satisfying. There is good correspondence in 67% of the comparisons, but the reliability indexes ( $\alpha = 0.3$  for friendly communications,  $\alpha = 0.6$  for neutral communications and  $\alpha = 0.45$  for unfriendly communications) are quite low.





the subjects' conflicts and accidents. The reader will see, though, that many of the correlations are significant but numerically low, which possibly leads to type I errors in interpretation. Further research will have to show if our way of interpreting the data is correct in all cases.

7.2.1. *Relations of driving errors to conflicts on the test route.* Two results should be mentioned initially.

(i) Drivers showing more errors than others in driving behavior get involved in conflicts significantly more often than others ( $r = 0.4$ ;  $p < 0.01$ ).

(ii) errors in driving behavior show a significant relationship to traffic conflicts caused or partly caused by the subjects themselves ( $r = 0.54$ ;  $p < 0.01$ ).

If the errors in driving behavior are divided into special groups of errors, significant relationships between the types of errors represented in Table 1 and traffic conflicts become evident.

7.2.2. *Relations of communication processes to traffic conflicts.* In the course of our driving-tests we registered 286 traffic conflicts: 47% of them occurred without communication between the various road users; 11% resulted from an absence of actually necessary communication and 42% happened in the course of actual communication (see Table 2).

In 37% of the conflicts registered during communication processes (45 conflicts), misunderstandings between the traffic participants concerned could in fact be noticed. Those are 16% of all conflicts registered. That means that 27% of all conflicts are at least partly due to avoidance of communication or misunderstandings.

When considering communication processes from another point of view, namely, distinguishing between friendly, unemotional and unfriendly communication styles, the data show

Table 1. Errors in driving behavior related to traffic conflicts

|   | CC *               | SUMAC **           |
|---|--------------------|--------------------|
| risky passing manoevers   | 0,13 <sup>†</sup>  | 0,15 <sup>†</sup>  |
| speed badly adapted to the traffic-situation                    | 0,16 <sup>†</sup>  | 0,26 <sup>††</sup> |
| tardy or absent deceleration at inter-sections or on approaches | 0,43 <sup>††</sup> | 0,13 <sup>†</sup>  |
| distance to preceding car too short                             | 0,20 <sup>††</sup> | 0,25 <sup>††</sup> |
| unlawful behavior at traffic-lights                             | 0,13 <sup>†</sup>  | 0,16 <sup>†</sup>  |
| not keeping one's lane  | 0,39 <sup>††</sup> | 0,13 <sup>†</sup>  |
| driving in the middle of the street                             | 0,19 <sup>†</sup>  | 0,13 <sup>†</sup>  |
| lane changing to avoid an obstacle only at the last moment      | 0,19 <sup>†</sup>  | -0,06              |
| hesitant lane-changing  | 0,23 <sup>††</sup> | 0,01               |
| risky lane-changing   | 0,47 <sup>††</sup> | 0,07               |
| cutting curves or corners                                       | 0,24 <sup>††</sup> | -0,05              |
| taking others' right-of-way                                     | 0,26 <sup>††</sup> | -0,01              |
| insisting on one's own right-of-way                             | 0,16 <sup>†</sup>  | 0,07               |
| jerky steering  | 0,32 <sup>††</sup> | 0,05               |
| inadequate lateral distance                                     | 0,28 <sup>††</sup> | 0,10               |
| absence of precaution at intersections                          | 0,36 <sup>††</sup> | -0,17 <sup>†</sup> |

\* Conflicts caused re. partly caused by the subjects

\*\* Sum of accidents caused or partly caused by the subjects according to their self responses in the exploration-talk

†  $p < 0,05$

††  $p < 0,01$

Table 2. Conflicts without communication, in the absence of in fact necessary communication and with actual communication

|                            | conflicts |     |
|----------------------------|-----------|-----|
|                            | n         | %   |
| no exchange of information | 135       | 47  |
| avoidance of communication | 37        | 11  |
| actual communication       | 121       | 42  |
|                            | 293       | 100 |

that in 33% of all conflicts, the communication was unfriendly. The correlation showing the relationship between conflicts during the driving observation and unfriendly communication is  $r = 0.19$  ( $p < 0.05$ ) or  $r = 0.26$  ( $p < 0.01$ ) between unfriendly communication and those conflicts which were at least in part the blame of the subject.

7.2.3. *Relations of traffic conflicts to the accident record mediated by amount and types of errors in driving behavior.* Three results have to be mentioned in this connection.

(i) Persons who committed more errors during the driving observation period report more accidents caused or partly caused by themselves ( $r = 0.014$ ;  $p < 0.05$ ); and, as one can read in Section 7.2.1, they also get involved in more traffic conflicts.

(ii) High insurance rate drivers show significantly more errors than low insurance rate drivers. On the average, the low insurance rate drivers commit 4.4 errors; the high insurance rate drivers, 6.1 errors. This difference is significant at the 1% level in a *t*-test. On the other hand, high insurance rate drivers cause or partly cause more conflicts on the test route, too (0.82 versus 0.58). This difference is not statistically significant, though.

(iii) Some of the coding variables showing relationships to the self-reported accident record (SUMAC; see Table 3) are at least slightly related also to the traffic conflicts the subjects caused or partly caused (CC) on the test route. The correlations between risky passing manoeuvres respective to unlawful behavior at traffic lights and CC are very low, though. Between speeding (e.g. driving at a speed above the speed limit, even if the situation respective to the traffic flow allow it) and CC no correlation at all appears, although there seems to be quite a satisfying relationship to accidents in the past.

One can see that only few variables show relations to traffic conflicts on the test route and to the subjects' accident record. This is contradictory to the reasoning in the beginning of

Table 3. Errors related to the reported accident record

|  | CC*                | SUMAC**            |
|--|--------------------|--------------------|
| risky passing manoeuvres                     | 0,13 <sup>†</sup>  | 0,15 <sup>†</sup>  |
| speed badly adapted to the traffic situation | 0,16 <sup>†</sup>  | 0,26 <sup>††</sup> |
| speeding                                     | -0,03              | 0,32 <sup>††</sup> |
| distance to preceding car too short          | 0,20 <sup>††</sup> | 0,25 <sup>††</sup> |
| unlawful behavior at traffic lights          | 0,13 <sup>†</sup>  | 0,16 <sup>†</sup>  |

\* Conflicts caused re. partly caused by the subjects  
\*\* Sum of accidents caused or partly caused by the subjects according to their self responses in the exploration talk  
†  $p < 0.05$   
††  $p < 0.01$

Table 4. Errors which are related to traffic conflicts, but not to the subjects' accident record

|  | CC *    | SUMAC ** |
|--|---------|----------|
| lane changing to avoid an obstacle only at the last moment | 0,19 †  | -0,06    |
| hesitant lane-changing                                     | 0,23 †† | 0,01     |
| risky lane-changing  | 0,47 †† | 0,07     |
| cutting curves or corners                                  | 0,24 †† | -0,05    |
| taking others' right-of-way                                | 0,26 †† | -0,01    |
| jerky steering   | 0,32 †† | 0,05     |
| inadequate lateral distance                                | 0,28 †† | 0,1      |
| absence of precaution at intersections                     | 0,36 †† | -0,17    |
| insisting on one's own right-of-way                        | 0,16 †  | 0,07     |

\* Conflicts caused re. partly caused by the subjects  
\*\* Sum of accidents caused or partly caused by the subjects according to their self responses in the exploration talk  
†  $p < 0,05$   
††  $p < 0,01$

this report. Although the sum of errors, registered by the free observer independently of their type, is related to CC as well as to the accident record, only few types of errors seem to be prestages as well of conflicts as of accidents.

Badly adapted speed and too short distances to the preceding cars are the only types of errors showing acceptable correlations as well to CC as to SUMAC (Table 3). Other variables (speeding, risky passing maneuvers, unlawful behavior at traffic lights) are not at all, or not satisfyingly related to CC, but show acceptable or quite good correlations with SUMAC (Table 3). Still others are quite clearly related to CC not showing, however, any relationship to SUMAC (Table 4).

If, considering all persons, there is no correlation between traffic conflicts during the driving test and the accident record, it can be assumed that all these types of errors are not distributed homogeneously among the various groups of subjects. According to this assumption, only some of the subjects commit errors which are related to traffic conflicts as well as to the accident record. Other drivers generally commit errors which are related to traffic conflicts during the driving test but not to any accidents in the past; still others commit errors which are related to the accident record, but not to their conflicts on the test route.

We thus established the following rough classification of drivers into four groups<sup>2</sup>.

- Group 1: many conflicts ( $n > 1$ ;  $\bar{X} = 2.89$ )  
many accidents ( $n > 1$ ;  $\bar{X} = 4.50$ )  
17.9% of the sample
- Group 2: few conflicts ( $n \leq 1$ ;  $\bar{X} = 0.45$ )  
many accidents ( $n > 1$ ;  $\bar{X} = 4.89$ )  
30.1% of the sample
- Group 3: many conflicts ( $n > 1$ ;  $\bar{X} = 3.03$ )  
few accidents ( $n \leq 1$ ;  $\bar{X} = 0.89$ )  
23.1% of the sample
- Group 4: few conflicts ( $n \leq 1$ ;  $\bar{X} = 0.47$ )  
few accidents ( $n \leq 1$ ;  $\bar{X} = 0.87$ )  
28.8% of the sample.

<sup>2</sup>In 1984, 100 more driving tests are planned. One of the aims with them is to examine if the same typology results once more.

Table 5. Some ratios\* showing significant differences between the four groups of drivers ( $p < 0.05$ , tested with Kruskal-Wallis)

|  | $\bar{Q}_{G1}$ | $\bar{Q}_{G2}$ | $\bar{Q}_{G3}$ | $\bar{Q}_{G4}$ |
|--|----------------|----------------|----------------|----------------|
| risky passing manoeuvres                                       | 0,78           | 0,30           | 0,22           | 0,53           |
| speed badly adapted to the traffic situation                   | 1,34           | 0,47           | 0,95           | 0,58           |
| speeding   | 3,14           | 2,55           | 2,2            | 1,93           |
| tardy or absent deceleration at intersections or on approaches | 0,67           | 0,21           | 0,58           | 0,21           |
| taking others' right-of-way                                    | 0,96           | 0,34           | 1,1            | 0,25           |
| Absence of precautions at intersections                        | 0,15           | 0,1            | 0,39           | 0,15           |
| insisting on one's own right-of-way                            | 3,63           | 2,95           | 5,05           | 2,17           |
| hesitant lane-changing   | 0,08           | 0,05           | 0,26           | 0,04           |
| distance to preceding car too short                            | 1,77           | 1,09           | 1,02           | 0,03           |

\* Ratio  $Q = \frac{f(B_E)}{f(B)} \cdot 10$ , where  $f(B_E)$  is the frequency of erroneous behavior within the coding variable and  $f(B)$  is the frequency of all codings within the same variable

Within these four groups the distribution of the types of errors varies considerably (see Table 5).

Table 6 shows the recordings of the free observers for the four driver categories (namely, deviations from standard behavior, communications and conflicts) as well as their self-reported accident record.

The age and driving experience of our four groups are shown in two graphs (Figs. 3 and 4).

The four conflict accident types of drivers could be described by means of the above mentioned data (Tables 5 and 6, Figs. 3 and 4) as follows.

Table 6. Free observation recordings and accident record of the four driver categories

|   | $\bar{X}_{G1}$ | $\bar{X}_{G2}$ | $\bar{X}_{G3}$ | $\bar{X}_{G4}$ |
|---|----------------|----------------|----------------|----------------|
| Errors in driving behavior†                                   | 7,11           | 4,26           | 9,03           | 2,96           |
| Ideal behavior  | 1,68           | 1,17           | 1,14           | 1,07           |
| Friendly communications                                       | 1,50           | 2,0            | 1,11           | 1,58           |
| Neutral communications  | 1,36           | 0,45           | 1,56           | 0,56           |
| Unfriendly communications†                                    | 5,86           | 4,55           | 5,72           | 5,00           |
| Conflicts on the test route†                                  | 2,89           | 0,45           | 3,03           | 0,47           |
| Conflicts caused re. partly†<br>caused by the subjects        | 1,85           | 0,19           | 1,92           | 0,20           |
| Sum of accidents reported †                                   | 4,50           | 4,89           | 0,89           | 0,87           |
| Sum of accidents not caused †<br>by the subjects              | 1,96           | 2,04           | 0,42           | 0,40           |
| Sum of accidents caused or<br>partly caused by the subjects † | 2,54           | 2,85           | 0,47           | 0,47           |

† Differences significant at the 5 %-level, tested with Kruskal-Wallis

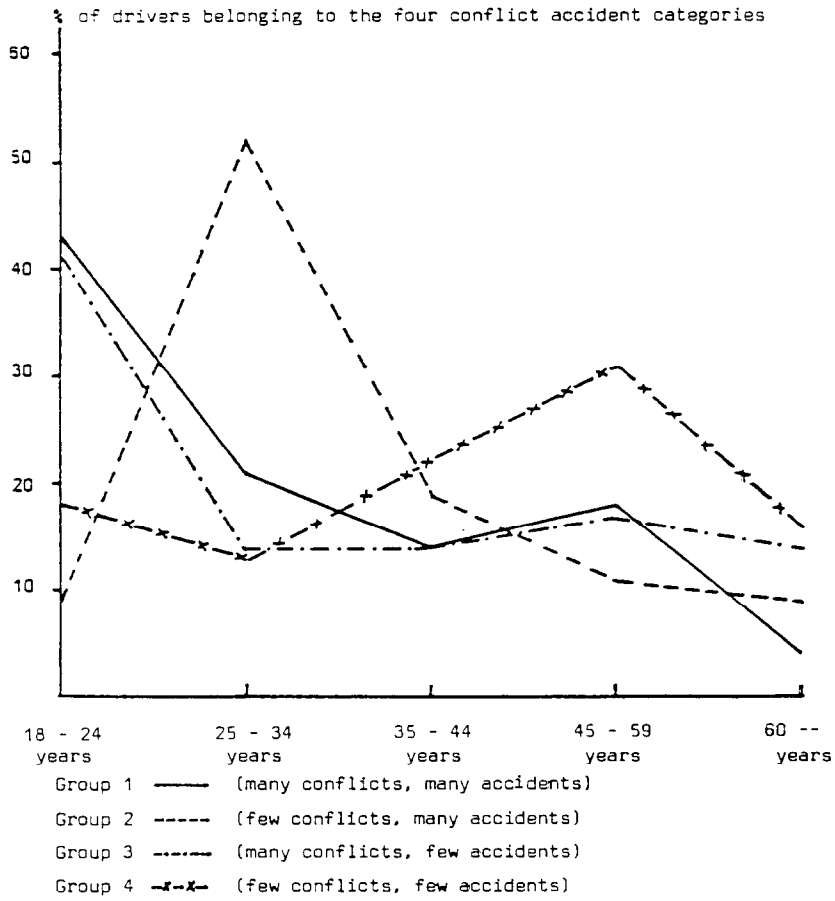


Fig. 3. The four driver conflict accident categories in relation to age.

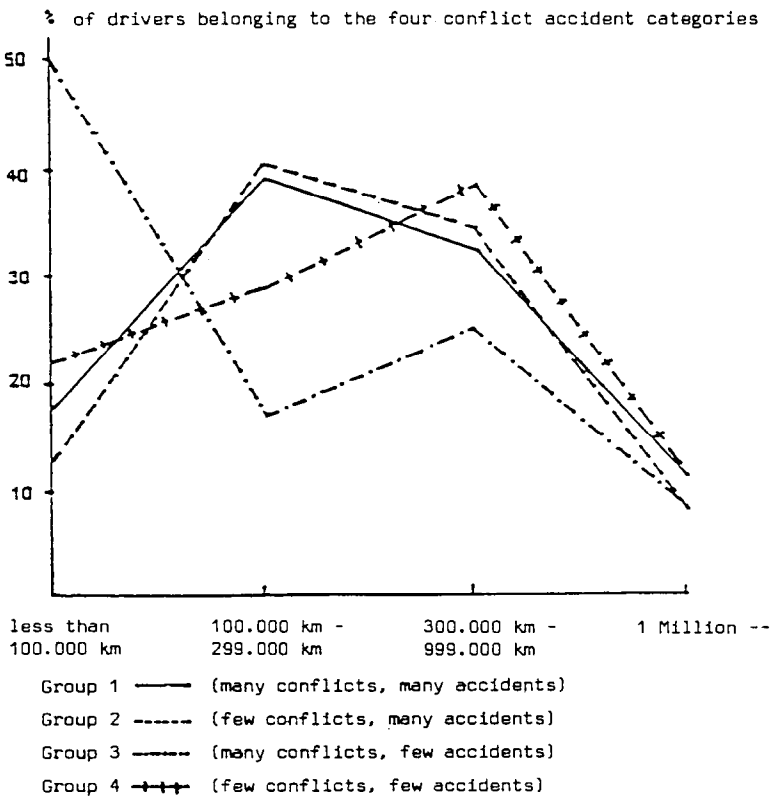


Fig. 4. The four driver conflict accident categories in relation to driving experience.

*Group 1.* Drivers of Group 1 commit many errors which are related to traffic conflicts as well as to their accident history. In this group a relationship between conflicts and accidents is probable. Drivers of Group 1 often pass precariously, change lanes in a dangerous way, exceed the speed limit more often (in a manner that is not compatible with the situation), often keep too little distance to the car ahead and often observe traffic lights more carelessly than those of the other groups.

This first group is principally composed of drivers between the ages of 18 and 24 years (30% of this age group represent 43% of Group 1). Relatively often also persons between 25 and 34 years can be found in this group (14% of this age group represent 21% of Group 1).

Most drivers report having between 100 000 and 1 000 000 kilometers driving experience. If this is correct and not merely youthful bragging, then Group 1 includes the youngest drivers on the one hand who, on the other hand, cannot be described as beginners. They certainly have enough experience as far as the handling of the car is concerned and obviously by now feel self-confident enough to drive fast and risky, which might be considered a function of age.

*Group 2.* These drivers (few conflicts, many accidents) receive fairly good ratings in the free observation. In any case they commit less errors than the drivers of Groups 1 and 3. But it seems they avoid particularly those errors which only play a minor role in accident-genesis. They move to the proper lane in time, reduce their speed in time when approaching intersections, behave correctly at intersections (if they do not have the right-of-way) and always seem to be on guard.

On the other hand, they often drive at high speed and keep too little distance to the car ahead. Compared with Group 4 they tend to insist on their own right-of-way. The drivers of Group 2 give signals sparingly. They have the least amount of contact with other traffic participants. In the final analysis, drivers of this group seem to commit the critical errors, or exactly those errors which can hardly be compensated by others: It is difficult and sometimes impossible to compensate for too high a speed or the exaggerated proximity of another traffic participant.

In Group 2 we can find many more drivers between 25 and 34 years than in Group 1 and significantly fewer drivers between 18 and 24 years. But only 38% are older than 34 years. Concerning driving experience, there is not much difference in comparison to the drivers of Group 1, only that slightly fewer drivers of Group 2 classify themselves as beginners with less than 100 000 km driving experience.

Drivers of both groups seem to emphasize the behavior patterns characteristic of young, experienced drivers. But often, experience seems to be lacking. It is evident that especially young drivers seem to overestimate their own driving capability (maybe by overestimating the number of kilometers they have been driving up to now). The consequence is that they overburden themselves and the probability of becoming involved in an accident increases considerably.

*Group 3.* Drivers of Group 3 (many conflicts, few accidents) commit many errors while driving on the test route. But obviously they do not commit those errors which result in accidents. They change lanes too late and in a hesitating manner, behave incorrectly at intersections notably often (e.g. they drive off at the wrong moment). They do all these things rather slowly and un rhythmically, giving the impression of feeling insecure. But because of these errors they also give the impression of being almost too cautious, not only to the observer but also to other traffic participants.

In addition to the above mentioned errors—which because of their slowly paced execution can be more readily compensated by others—drivers of Group 3 are, in general, quite unfriendly when communicating with other traffic participants. This unfriendly behavior most probably results from insecurity and also contributes to warn the other participants to exercise caution in their vicinity.

Nevertheless, drivers of Group 3 do not commit critical errors such as risky passing, driving too fast and keeping too little distance to the car ahead. Characteristic for drivers of Group 3 is their age as well as their driving experience: 46% of all persons with little driving experience (less than 100 000 km so far) represent 50% of Group 3 drivers; 78% of them are younger than 25 years.

It should be noted that about  $\frac{1}{3}$  of our subjects who are older than 60 years also belong to Group 3. They obviously commit errors which one would consider to be characteristic for beginners. It seems that with increasing age it gets more difficult to compensate decreasing performance even by means of an extensive driving experience.

*Group 4.* Drivers of Group 4 (few conflicts, few accidents) represent the "ideal driver." They can be described most easily: they rarely commit any kinds of errors. They do best concerning the variables speed, keeping distance, as well as changing and keeping lanes.

Characteristic for drivers of Group 4 is their age (69% of them are older than 35 years) as well as their driving experience (78% of them report more than 100 000 km driving experience).

*7.2.4. Solution of conflicts.* Table 7 shows how conflicts are solved. The most common reaction to conflict situations was, as we had expected, deceleration. This reaction is typical for conflicts at intersections (sometimes accompanied by jerky steering movements) as well as for conflicts with pedestrians crossing the road. In lane-changing conflicts drivers also often react by slowing down; in these situations jerky steering movements are observed at least equally frequently. However, most of these conflicts are solved by means of a combination of both possibilities.

In contrast to our expectations, conflicts were also quite frequently solved by accelerating (in more than 10% of all cases). The explanation is that the subjects had to turn left relatively often along our route (with the possibility of encountering oncoming traffic). There are also some intersections where the drivers do not have the right-of-way and, due to the constructional conditions, have to drive out into the crossroad quite long before being able to view the actual traffic situation. In both cases it might just be that the drivers who want to turn left or want to cross the intersection accelerate in order to avoid an accident or to get out of the danger zone.

Characteristically, those drivers who are quite often involved in conflicts rarely contribute to their solution (Table 8).

Does that express stress or inadequate perception? A combination of both hypotheses is most likely. In conflict situations freedom of options is up to a certain degree a critical factor in reacting adequately and in time. Several situations, however, are not perceived as conflicts by the subjects; therefore, a quick reaction does not seem necessary to them. Are some traffic participants already used to the fact that others compensate their inadequate behavior?

Anyway, the classification of persons by means of observing the way in which they contribute to the solution of conflicts will be part of future research at our institute.

### 7.3. The relation of traffic conflicts to accidents on the intersections of the test route

We looked for better and clearer correlations between accidents and conflicts than we had got comparing our subjects' accident records and their conflicts on the test route. In this part of our study we thus tried to investigate in a most simple way whether locations where accidents happen frequently correspond to those locations where conflicts were frequently registered. If the results were encouraging, this study would provide initial pointers to those sites which should be subjected to scrutiny in a followup study. Before starting to analyze the correlations

Table 7. Evasive actions

|                    | subjects |    | other traffic participants |    |
|--------------------|----------|----|----------------------------|----|
|                    | n        | %  | n                          | %  |
| deceleration       | 80       | 56 | 70                         | 58 |
| acceleration       | 13       | 13 | 12                         | 10 |
| steering maneuvers | 45       | 31 | 38                         | 32 |
| n                  | 143      |    | 120                        |    |

Table 8. Participation in conflict solving in relation to the four groups of drivers

| groups                                 | group 1 | group 2 | group 3 | group 4 |
|--|---------|---------|---------|---------|
| % of participation in conflict solving | 67      | 51      | 55      | 66      |

between the observation variables registered on the sections of the test route and the frequencies of accidents on those same sections, some restrictions had to be made.

Long, straight segments with several intersections had to be excluded. Therefore, the number of sections to be analyzed was reduced.

On some crossroads of the test route there is the possibility that vehicles cross against the flow of traffic along our route.

By eliminating these crossroads, too, we find 13 remaining sites where only vehicles driving in the direction of our route could be involved in accidents.

But it is possible to get at least rough data for all crossroads with possible interactions between vehicles against the flow of traffic along our route by estimating the percentage of those accidents in which vehicles travelling along our route could have been involved (see Figure 5).

The intersection shown in Fig. 5 provides 44 possibilities for vehicles to cross. But only 8 of them concern the flow of traffic of our test route. That is  $\frac{8}{44}$  (approximately  $\frac{1}{5}$ ) of all the possibilities for vehicles to cross at this intersection. By means of taking one-fifth of the number of accidents it is possible to achieve a rough estimation of the number of accidents in which vehicles driving in the direction of our route could have been involved.

The intersection presented in Figure 5 shows the highest degree of complexity we permitted in our evaluation. More complex sites were excluded.

Together with the above-mentioned 13 clearly defined sites, 37 locations remained for which we investigated the relation between accidents and conflicts. Table 9 shows the results of this investigation.

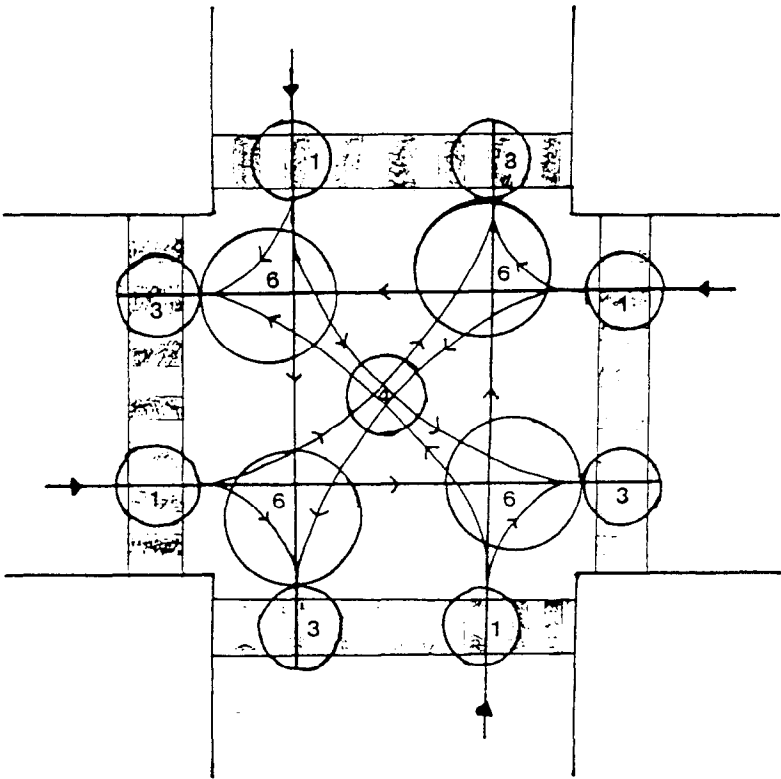


Fig. 5. Number of crossing possibilities on a rectangular intersection.



Table 9. Relations between accidents and conflicts calculated for 37 sites

|   | CC *    | C **    |
|---|---------|---------|
| ...<br>AV 3 (accidents with severe injuries<br>in the year 1981)                            | 0,59 †† | 0,73 †† |
| AV 4 (total number of accidents with<br>injuries in the year 1981)                          | 0,46 †† | 0,55 †† |
| AV 5 (accidents with vehicle damage<br>which were reported in 1981)                         | 0,53 †† | 0,52 †† |
| AV 6 (accidents with severely injured<br>from the years 1976-1980)                          | 0,45 †† | 0,57 †† |
| AV 7 (total number of accidents with<br>injuries from the years 1976-1980)                  | 0,52 †† | 0,62 †† |
| AV 8 (accidents with vehicle damage<br>which were reported in the<br>period from 1976-1980) | 0,52 †† | 0,49 †† |

N = 37

\* CC = Conflicts caused or partly caused by the subjects

\*\* C = Total number of conflicts the subjects got involved in

... AV = Accident variable

††  $p < 0,01$ 

The results show that on those sites where accidents happened more frequently, more conflicts were also registered.

## 8. SUMMARY AND DISCUSSION OF RESULTS

We wanted to study behavior of road users in traffic conflict situations in order to get hints about behavioral details which raise the probability of accidents. But it is not guaranteed that behavior leading to traffic conflicts also influences the probability of accidents. Therefore, apart from the analysis of special behavior observed before, during and after traffic conflicts, we wanted to find out possible relations of traffic conflicts to accidents. Results concerning these two questions will now be summarized in the following sections.

### 8.1. Traffic conflicts as indications for accident-risk

Our only possibility to get data about accidents was at first to ask subjects about their driving record. Some evidence for the accuracy of the accident data obtained in the exploration talks could, however, be derived from data concerning the subjects' belonging to the low versus high insurance rate group submitted by the insurance companies. Drivers belonging to the high insurance rate group reported significantly more accidents during the past five years.

Accident data obtained in exploration talks, however, are not related to traffic conflicts. 201 subjects got involved in during a one hour's driving test on a standardized test route. On the other hand, if one looks at the relationships between traffic conflicts observed in our experiment and accidents counted on 37 sections of our test route in the years 1976-1981, the results are much more satisfying. On those sites, where accidents happened more frequently, more traffic conflicts were registered, too.

### 8.2. Possible prestages of traffic conflicts and accidents

Analyzing the subjects' behavior during the driving test it is possible to find certain types of behavior that show relations to traffic conflicts also registered during their driving tests as well as to accidents they were involved in during the past five years. Badly adapted speed and too short distances to the preceding cars are such types of behavior.

Summing up all types of errors in driving behavior (negative deviations of the behavioral standard) one also can find relations of this sum of errors to traffic conflicts as well as to accidents. The sums of all errors in driving behavior show correlations with the subjects'

accidents in the past five years as well as with the subjects' traffic conflicts during one hour's driving test.

### 8.3. *Is speeding badly estimated by the observers?*

Free observers were not to register speeds within 20 km/h above the speed limit as errors (that corresponds with speed exceedings tolerated by the Vienna City Police) except for situations such a speed was judged as dangerous. Coding observers, however, had to register "adapted speed, though above the speed limit." Surprisingly, frequent driving above the speed limit (registered by the coding observers) not rated as driving error by the free observers, shows quite a high correlation with the number of traffic accidents caused or partly caused by the subjects during the past five years ( $r = 0.32$ ;  $p < 0.01$ ) as well as quite a high correlation with all the accidents they got involved in during the same time ( $r = 0.27$ ;  $p < 0.01$ ).

For further driving tests we will obviously have to change our concept of "adapted speed, though above the speed limit."

### 8.4. *Awkward behavior*

There is a number of types of behavior that can best be described with the word "awkward," like lane changes to avoid obstacles at the last moment, hesitant lane changes, risky lane changes, cutting curves or corners, taking others' right-of-way, inadequate lateral distance, absence of precautions at intersections, insistence on one's own right-of-way and jerky steering. Persons frequently showing those types of behavior quite often get involved in traffic conflicts. At the same time they quite rarely contribute to the solution of those conflicts. It seems that other road users compensate their errors. Persons frequently behaving awkwardly report very few accidents during the past five years. Another characteristic for awkwardly behaving road users is their way of communicating. They often communicate in an unfriendly way with other road users. We took that as a hint that behavior perceived as unfriendly by other road users quite often does not result from presumptuousness but rather from insecurity and stress.

### 8.5. *Four groups of drivers*

As an illustration of our observation results we described four groups of drivers.

(i) The group described in Section 8.4 (which is Group 3 in our classification) includes drivers badly assessed due to their frequent errors, traffic conflicts and unfriendly communication during the driving test. However, they report only few accidents during the past five years. That could be due to the fact that many beginners belong to this group who did not have many possibilities to get involved in accidents, yet; on the other hand, a high percentage of persons older than 60 years belong to this group, too. Possibly other road users pay more attention to older drivers and compensate their unadjusted behavior. Maybe as far as the older drivers are concerned the driving test is a hint for a higher accident risk in the future although their unadjusted behavior did not lead to accidents up to now.

(ii) Another group of badly assessed drivers (Group 1) show all types of behavior that are related to traffic conflicts as well as to accidents. Accordingly they got involved in many traffic conflicts during the driving test and they reported many accidents during the past five years. Many young drivers (18–34 years) belong to this group, most of them reporting a driving experience of more than 100 000 km, though.

(iii) In Group 2 the percentage of drivers between 25 and 34 years is distinctly higher than in all the other groups. Drivers of this group report slightly more kilometers of driving experience than drivers of Group 1. Their behavior is assessed quite well, although analysis of their driving record shows that they were involved in approximately as many accidents as drivers of Group 1. During the driving test they do not commit many errors of any kind, are not involved in many traffic conflicts and communicate in an unobtrusive way. Only frequent driving above the speed limit—but within the 20 km/h margin—could be labeled as unadjusted behavior in this group.

(iv) The fourth group of drivers mainly consists of persons older than 34 years (70%), approximately 50% of them reporting more than 300 000 km driving experience. They commit only very few errors of all types, get involved in very few traffic conflicts on the test route and report very few accidents during the past five years.

This classification of drivers in four groups has two advantages. It mediates a plausible connexion between drivers' age, driving experience and driving behavior, and it illustrates the relations of behavior in traffic conflict situations to the accident record.

### 8.6. *The importance of communication*

Erroneous communication or lack of actually essential communication are types of behavior often observed in connection with traffic conflicts. Moreover, special types of communications certainly contribute to the atmosphere of the traffic situation typical for a city, a region, or a country. The quality of communication in Vienna is certainly better than we had expected considering the results of a former study [Risser *et al.*, 1981].

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